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Atomic number and energy dependence of absorption in beta particles

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The mass absorption coefficients μ for 0·430, 0·765, 1·17 and 1·71 MeV beta particles have been determined in aluminium, copper, silver, tin, gold and lead absorbers using a plastic scintillation beta detector. The dependence of absorption on the end point energy (E) of the beta particles and the atomic number (Z) of the absorber is studied and an empirical relation of the type $\mu = 0{\cdot}0061\, E^{-1{\cdot}23} Z^{0{\cdot}366} E^{-0{\cdot}069}$ is obtained. A comparison of the values of μ based on this relation with the available measured and calculated values is made and discussed.

1. Introduction

Much work has been done on the interaction of beta particles with matter. For purposes of measuring the energy of the radiation, either for the identification of unknown radio element, or for the establishment of a decay scheme, for choosing thickness of the target materials, shielding materials etc., we need to know the absorption and transmission of beta particles in matter with considerable accuracy. Apart from this, the determination of the exact fraction of incident beta particles, photoelectrons, Auger electrons and the like that is transmitted by an absorbing specimen is of great importance in nuclear spectroscopy, which is usually evaluated with some absorption or transmission curves.

In the literature there is no simple analytical formula available for the absorption of beta particles in matter. But there are empirical relations for the absorption in aluminium. Gleason *et al* (1951) studied the energy dependence which is based on their experimental results of absorption of beta particles with different end point energies in aluminium using a G.M. counter. Recently Mudhole (1973) showed that experimentally determined mass absorption coefficients are independent of the atomic number of the absorber, which is in contradiction with the proposed dependence of absorption on the atomic number given by Evans (1955). We have studied the absorption of beta particles in different elements with different beta sources. For this purpose the elements whose atomic numbers range from 13 to 82 (aluminium, copper, silver, tin, gold and lead) and beta particles with end point energies from 400 KeV to 1700 KeV (430, 765, 1170 and 1700 KeV of ^{185}W, ^{204}Tl, RaE and ^{32}P) were used. The mass absorption coefficients were determined using a plastic scintillator as beta detector.

Based on the present experimental results a simple empirical relation for mass absorption coefficient is obtained and discussed.

2. Theoretical Background

When electrons pass through matter, they suffer a degradation of their kinetic energy by means of various interaction processes such as excitation, ionization, elastic collision and radiative collision as reviewed by several authors The bremsstrahlung process is negligible at low energies. At those energies degradation of the incident beam occurs only due to the interaction with the atomic electrons of the target materials. For beta particles of continuous energy, an exponential absorption law is approximately valid and this type of exponential absorption is observed down to 1% of beta transmission (Evans 1955) The mass absorption coefficient can be determined by studying the absorption in the target material of different thicknesses and is given by

$$\mu = -(1/t)\ln(N/N_0) \qquad \ldots \quad (1)$$

where N/N_0 is the fraction of the incident beam that is transmitted through a thickness t (mg/cm^2) of the absorbing material. It is known that μ depends primarily on incident beta end point energy E (in MeV) and also slightly on the atomic number Z of the absorber . So, the relation for μ can be of the type

$$\mu = KE^aZ^b \qquad \ldots \quad (2)$$

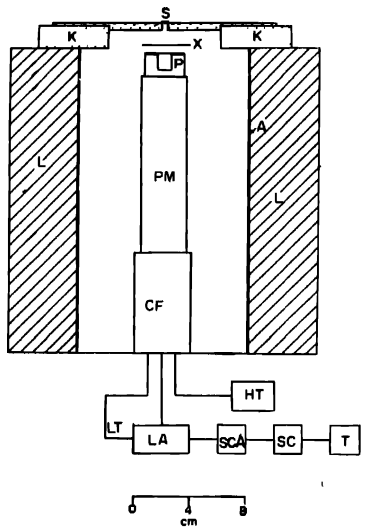
Here K, a and b are constants, which can be evaluated using values of μ calculated from eq (1)

3. Experimental

A schematic diagram of the experimental setup used is shown in figure 1. It is similar to the setup used by Gleason *et al* (1951) except for the detector; Instead of the G.M. Counter, we have used a well-type plastic scintillator (NE-102) which has got 100% efficiency for beta particles The size of the well was 0·7 cm dia and 1·2 cm depth in a 2·8 cm dia and 1·5 cm thick crystal This was coupled to a RCA 6199 photomultiplier and it was covered with a black adhesive tape. The pulses from the detector were fed through a linear amplifier to the counting system. The liquid beta sources of ^{185}W, ^{204}Tl, RaE and ^{32}P of strength 1 mCi each were obtained from Bhabha Atomic Research Centre, Bombay, India. Point sources of about 20–30 μCi strength were prepared on thin mylar films by the evaporation technique.

The fraction of the beta particles that is transmitted from a foil was measured by keeping the source at a distance of 2·2 cm from the detector with absorber foils placed in between the two. As the distance between the source and detector is

short, scattering is negligible compared to absorption and also there is very little air scattering. The geometry of the experiment was such that the size of the crystal well forms the base of the geometric cone. Also, this well type crystal reduces surface scattering The experiment was repeated for different thicknesses of the absorber foil. In all the cases the maximum thickness was limited to 0·4 times the range of the beta particles as the absorption is known to obey the exponential law in this range (Mudhole 1973). The counting statistics in all the cases was better than 2% The correction for absorption in air and crystal covering was applied to the counting rate to convert it to that which would be observed if the air and crystal covering were absent.

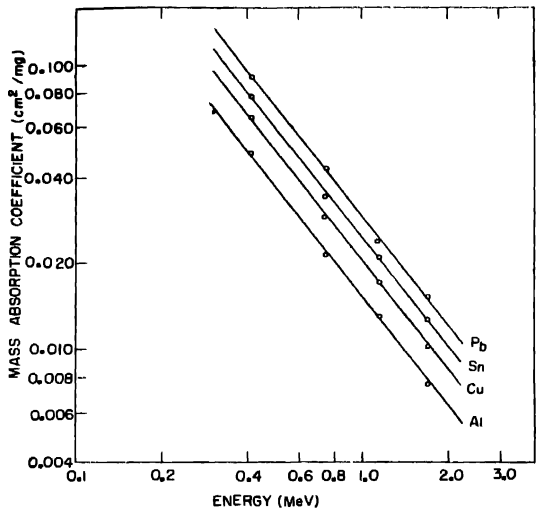


Fig, 1. Experimental setup :
S—source K—perspex collimation. X—absorber material. P—plastic scintillator. A—aluminium lining. L—lead shielding. PM—photomultiplier. CF—preamplifier. HT—high tension power supply. LT—low tension power supply. LA—linear amplifier. SCA—single channel analyser. SC—scaler and T—timer.

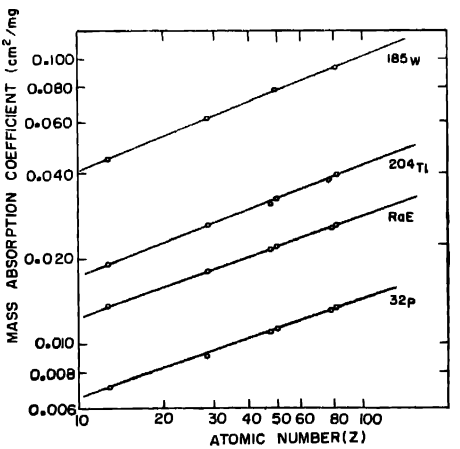
4 Results and Discussion

The mass absorption coefficients μ were determined for beta particles of ^{185}W, ^{204}Tl, RaE and ^{32}P in aluminium, copper, silver, tin, gold and lead absorbers by the method of least squares. The exponent a in the relation (2) is determined by plotting the mass absorption coefficient μ against beta end point energy E

(figure 2) while b is determined by plotting the mass absorption coefficient μ against atomic number Z (figure 3). The deviation in the value of exponent b is



Fig, 2, Plot of mass absorption coefficient μ against beta end point energy

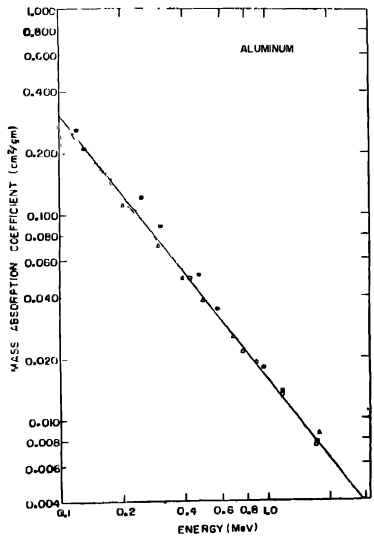


Fig, 3, Plot of mass absorption coefficient μ against atomic number of the absorbers.

found to vary slightly with the varying beta end point energy. Taking this into account and using the values of the exponents a and b so determined and the measured mass absorption coefficients in all the cases, the constant K in the relation (2) is calculated. The variation in K is also found to be less than 1% and the weighted average value turns out to be 0·0061. Using these values an empirical relation for μ is obtained as

$$\mu = 0.0061\, E^{-1.27} Z^{0.366} E^{-0.069} \qquad \ldots (3)$$

From this relation μ is calculated for energies from 100 KeV to 3 MeV in the case of aluminium. Figure 4 shows the plot of $\log \mu$ against $\log E$ for the



Fig, 4, Plot of mass absorption coefficient μ against beta end point,
— present relation.
O present experimental points.
O Gleason *et al* experimental points.
Δ calculated values obtained from Evans' relation,

above computed values. In same figure, measured values of Gleason *et al* and calculated values obtained from Evan's relation are plotted. The present measured values are lower than Gleason *et al* values. The agreement is better than 10%. To compare this relation for other Z materials, data are not available in the literature. Therefore we feel that our empirical relation is useful in deter-

mining the absorption of beta particles in different target materials in the specified energy range.

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